Demo: SierraNet: Monitoring the Snowpack in the Sierra Nevada

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Abstract

Next-generation hydrologic science and monitoring requires real-time, spatially distributed measurements of key variables including: soil moisture, air/soil temperature, snow depth, and air relative humidity. The SierraNet project provides these measurements by deploying low-power mesh networks across the California Sierra Nevada. This demo presents a replica of the end-to-end SierraNet monitoring system deployed in the Southern Sierra. This system is a highly reliable, low-power turn-key solution for environmental monitoring.

1 Relationship to Previous Work

This demo presents the SierraNet project and the associated deployment running in the Sierra Nevada. An overall description of the SierraNet project was previously published [**?**]. Some text and figures in this extended demo abstract are borrowed from that publication.

2 Introduction

Between 2012 and 2015, California suffered from the highest water drought since recordings started in this state. Up to 2/3 of its water resources are coming from the Sierra Nevada snowpack. Understanding the effect of the droughts on the mountain snowpack is crucial.

Until recently, snow melting and water displacement measurements were done by hand. This manual process is costly and not frequent enough to reflect the environment changes. There was a need for a dense (i.e. in time and space) monitoring solution to capture the spacial variability of the water.

The SierraNet project started in 2009 with the goal of monitoring the Sierra Nevada snowpack without human intervention. At the time of writing, 18 low-power wireless networks are deployed in the Sierra Nevada. They measure snow level, solar radiation, soil moisture, soil temperature, air temperature and air relative humidity in different locations. The SierraNet project currently includes the American River Hydrological Observatory (ARHO) project [**?**] with 985 sensors, and the Southern Sierra project [**?**] with 300 sensors.

3 SierraNet

3.1 The Deployments

The ARHO project deployments [**?**] are located in the 2000 km^2 American River Basin, above 1500 m altitude, in the central Sierra Nevada, near Sacramento, CA, USA. The ARHO project is designed to provide representative measurements of the snowpack, solar radiation and soil moisture, to enable real-time management of the state's water supply. It is the core element of a new water-resource information system, and a platform for improving Hydro-Electric generation operations using real-time data. The project consists of 945 sensors, organized in 14 independent low-power wireless networks. These networks are deployed in locations strategically chosen to get representative spatial estimates of snow cover, soil moisture and other water-balance components. Data from these sensors are integrated with forecasting models and decision-support tools.

The Southern Sierra deployment [**?**] is a forested 1 km^2 headwater catchment area. This 300-sensor deployment measures snow depth, solar radiation, relative humidity, soil moisture and matric potential. On top of environmental monitoring, this deployment is used to investigate low-power wireless repeaters placement strategies.

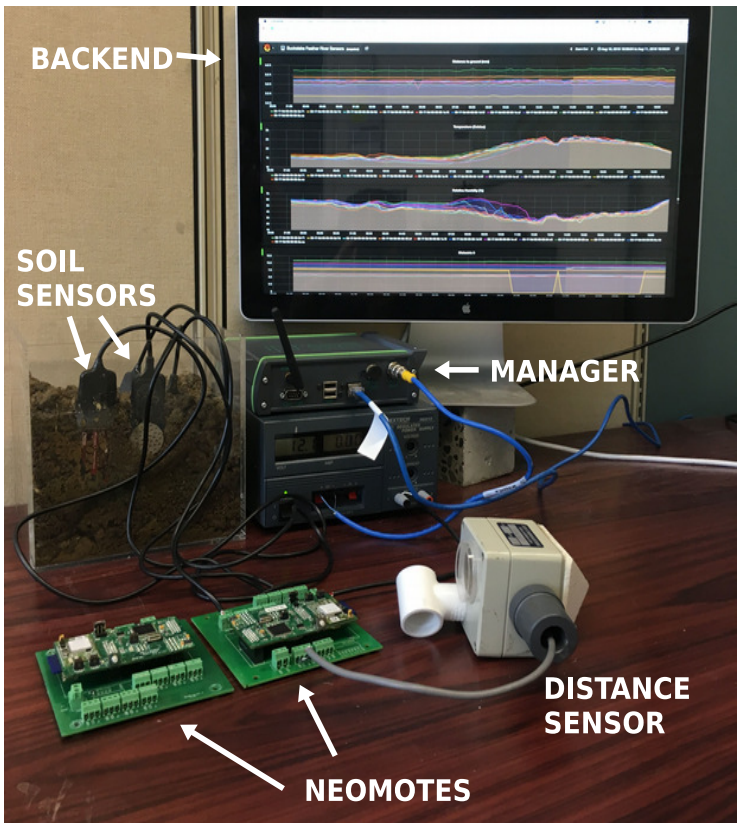

Figure 1: The setup of the SierraNet demonstration, including the motes, the manager, the sensors and the web interface of the back-end system.

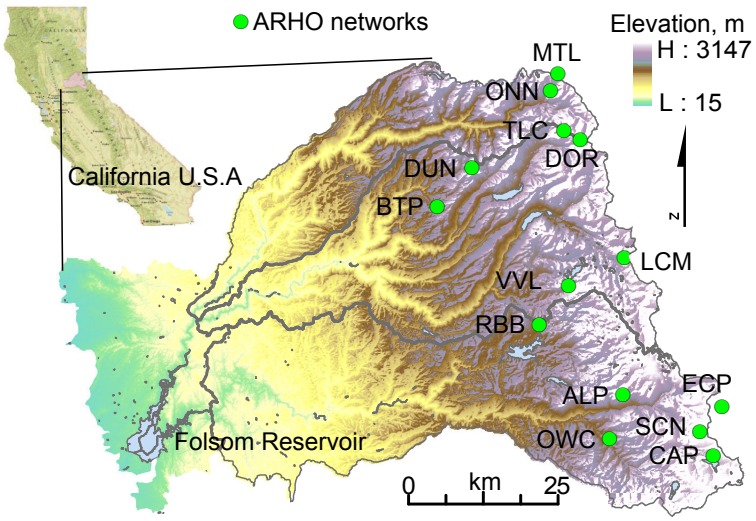

Figure 2: The 14 independent networks of the ARHO project.

3.2 The end-to-end System

Each network of the ARHO and Southern Sierra deployments share the same architecture. Sensor stations are placed in hydrologically-significant locations. Repeater nodes are added to ensure good connectivity. The sensor data is relayed to the manager node, which is connected to a Linux computer. This computer connects to the Internet through a satellite or cellular link. Seconds after the generated data is produced in the deployment site, it appears in the database and can be visualized online.

At the heart of each sensor station is a NeoMote, a low-power wireless platform commercialized by Metronome Systems, a UC Berkeley spin-off company. The NeoMote is a generic sensor platform, which features a Cypress PSoC microcontroller and a SmartMesh IP low-power wireless mote, in a hardened weatherproof design. The NeoMotes are using the SmartMesh IP technology to form low-power wireless networks with >99.999% end-to-end reliability and a over decade of battery lifetime [**?**].

The Southern Sierra devices were replaced by Neomotes in 2016; the network is now using the Sensor Object Library [**?**]. SOL allows the network to produce both sensor values and network statistics as augmented Type-Length-Value objects, facilitating data manipulation, query and visualization.

4 Related Deployment and Lessons Learnt

A similar network is deployed for monitoring and predicting frost events in Western Argentina [**?**]. The PEACH system measures air temperature and

relative humidity, soil moisture and soil temperature over a 110 m $\times$ 50 m peach orchard. The collected data is then analyzed with machine learning techniques to predict frost events.

Wireless sensor applications went promising research to using off-the-shelf products implementing standard-based technology. Adapting the system from a frost monitoring in peach orchard application to a snowpack monitoring is now an easy task. Low-power wireless mesh technology successfully transitioned from the academic to the commercial world.

5 The SierraNet Demo

The purpose of this demo is to present a fully-working replica of the low-power wireless mesh network currently running in the Southern Sierra as part of the SierraNet project. We deploy Metronome System motes in the conference venue. They automatically form a low-power wireless mesh network around the Metronome System network manager. Motes are equipped with air relative humidity sensors. The network manager is connected to the Internet. Sensor measurements and network statistics are sent to the network manager and forwarded to the back-end system running at Inria-Paris. Conference participants can observe the data live at `https://sol.paris.inria.fr/`.

This demo presents the deployed system as a turn-key solution for monitoring the environment with a low-power and highly reliable technology. We are looking for partners, end users and integrators to replicate the SierraNet system to other deployments and applications.

6 Acknowledgment

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